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## Automotive Gear Lubrication

By H. R. WOLF

Head, General Chemistry Department Research Laboratories Division

General Motors Corporation, Detroit, Mich.

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### INTRODUCTION

The principal criteria for judging the suitability of a gear lubricant, for use in the gear sets of the early model automobiles, were the ability of the lubricant to

- (1) reduce gear noise, and
- (2) decrease gear box leakage.

These requirements invariably resulted in the use of high viscosity mineral or compounded gear oils or soap thickened lubricants.

The modern gear set presents an entirely different picture. Noise and leakage are no longer controlling factors in the selection of gear lubricants. Materials of construction are employed more efficiently—gear size has been reduced; sliding velocity and load per unit area have been greatly increased. These changes have progressively imposed more severe duty on the gear lubricant until it has now become an integral part of the design.

### SELECTION OF GEAR LUBRICANT

The selection of a gear lubricant for any specific gear set involves a careful consideration of the lubrication requirements of the gear set and the performance characteristics of the gear lubricant.

The lubrication requirements of a given gear set, with reference only to the load-carrying or extreme-pressure properties of the lubricant, are determined by:

- (1) The inherent characteristics of the gear set, as controlled by type and design.
- (2) The service conditions under which the gear set is operated.

### PROPERTIES OF LUBRICANTS

#### AFFECTING PERFORMANCE IN SERVICE

The properties of a gear lubricant which

affect its performance in service, stated in terms of performance characteristics rather than as inspection or specification limits, are:

- (1) Ability to prevent scoring or scuffing of the gear tooth surfaces.
- (2) Freedom from tendency to cause wear of gear tooth surfaces and plain or anti-friction bearings.
- (3) Capacity to remove heat from gear tooth contact areas.
- (4) Stability in storage and service.
- (5) Freedom from tendency to cause corrosion of both ferrous and non-ferrous parts, either in the presence or absence of water.

The order of importance of these properties will, of course, vary in different gear applications.

### STEERING GEAR LUBRICANT

One of the principal requirements of a steering gear is the maintenance of maximum efficiency over a wide range in operating temperature. This requirement has led to the development of the "all-season" or "all-year" steering gear lubricant.

G. M. 4567-M is a representative example of the "all-season" type of steering gear lubricant. This lubricant employs a low viscosity, low pour point mineral oil, compounded with a sulphurized saponifiable oil, thickened to the proper consistency with a small amount of calcium soap. The sulphurized saponifiable oil imparts some extreme-pressure characteristics to the lubricant. However, it is used primarily to increase oiliness and to control the consistency of the finished lubricant over the range in temperature encountered in service. Through careful selection of the basic materials in-

volved, it is possible to manufacture a steering gear lubricant which will have the thermal property of one of the well known shaving creams, and actually become more fluid as the operating temperature is reduced.

The use of the "all-season" steering gear lubricant eliminates the necessity of periodic or seasonal changes. Consequently, many steering gears are no longer provided with a drain opening. It therefore becomes increasingly important to use only the "all-season" type in the service field for maintaining the lubricant at the proper level.

### TRANSMISSIONS

The transmission gears in passenger car service and in normal commercial car service are not stressed sufficiently to require an extreme-pressure lubricant to prevent scuffing or scoring of the gear tooth surfaces. In general a straight mineral oil will suffice so far as lubrication is concerned.

In passenger cars, except under extreme conditions of sustained high speed, the conventional black oils, which have been used for many years as transmission lubricants, will function satisfactorily. In heavy-duty commercial operations, where higher temperatures are involved, a highly refined mineral oil is required to avoid oxidation difficulties.

During the past several years the use of a high grade mineral oil compounded with approximately 15% of a sulphurized saponifiable oil has found considerable favor as a transmission lubricant. The sulphurized saponifiable addition gives a very limited improvement in load carrying capacity. This alone would not justify its use. The outstanding advantages—greater ease in shift-



ing and wider range in operating temperature—are due to the oiliness characteristics of the sulphurized saponifiable addition and to its action as a viscosity index improver.

Where a transmission lubricant of this type is used by the car manufacturer for the initial factory filling, its continued use in service is recommended by specifying an "E. P. Transmission Lubricant".

Truck transmissions, particularly when used under especially heavy-duty service conditions, may require extreme-pressure lubricants or may even require the more powerful types of lubricants used in hypoid rear axles. However, since practically all transmissions contain bronze parts, compatibility of the lubricant with the particular bronze used in the transmission in question, as well as load carrying characteristics, must be carefully considered.

#### AUTOMATIC TRANSMISSIONS

The lubrication requirements of the several types of semi-automatic and automatic or self-shifting transmissions now in use vary over a wide range. Until these types of transmissions have been standardized to a degree where one or two service fluids will cover the entire range without adversely affecting the performance of the units, the various types of fluids now in use should be considered as "service parts", and should be supplied by the equipment manufacturer in the same manner as other service or replacement parts.

The Hydra-Matic drive used by the Oldsmobile and Cadillac Divisions, of General Motors Corporation, requires a high viscosity index lubricant that is extremely resistant to oxidation. The commercial engine crankcase oils oxidize too rapidly and therefore do not function satisfactorily in the Hydra-Matic drive. Since lubricants of the required viscosity, stability and frictional characteristics are not available at the present time to car owners through the regular petroleum marketing channels, the Oldsmobile and Cadillac Service Departments are supplying to their dealers and distributors a special "Hydra-Matic Fluid" that has been thoroughly tested under actual service conditions.

The same general policy is followed by other automotive manufacturers in supplying special clutch and transmission lubricants.

#### REAR AXLES

The lubrication recommendations for any gear set must be based on the lubrication requirements under the most severe operation conditions that will be encountered in service. This is particularly true in the case of both passenger-car and truck rear axles.

Hypoid rear axle gears require a lubricant having a higher load carrying ability than spiral bevel gears. This is not due to fundamental differences between the two types

of gear sets. Spiral bevel gears that require the most powerful type of lead soap active sulphur hypoid lubricant to prevent scoring of the gear tooth surfaces can and have been designed. Conversely, hypoid gears can be designed to operate satisfactorily on straight mineral oils. In fact, many of the present production hypoid gear rear axles will operate at low speed under normal driving conditions on straight mineral oil without scoring. However, a design capable of operating satisfactorily under the most severe service conditions on straight mineral oil would require an extremely large and heavy gear set and would be impractical in both passenger cars and trucks.

A study of the scoring action of rear axle gear sets in service has very conclusively demonstrated that the factor PV (maximum tooth pressure in pounds per square inch, as calculated by the Hertz formula, multiplied by the rubbing velocity in feet per second) is an accurate index of the tendency of a specific gear set to score under service conditions. While no definite dividing line can be established for all types and designs of gears, a low PV value indicates satisfactory service on straight mineral oil, while a high PV value indicates that a lubricant capable of forming a solid film, which acts as an "anti-welding" flux to prevent metal to metal contact between the sliding or rubbing surfaces, is required.

Truck hypoid gears do not differ inherently in design from passenger car hypoid gears but they operate under somewhat different service conditions and, therefore, may require a different type of lubricant to prevent scoring.

A passenger car hypoid gear axle operates under the most severe lubrication conditions at high speed, whereas a heavy-duty truck hypoid axle operates under the most severe lubrication conditions at low speed with maximum engine torque in low gear.

Lead soap active sulphur hypoid lubricants have been used successfully in all makes of passenger car hypoid gear rear axles. These lubricants, when properly compounded, are stable under the operating conditions encountered in passenger cars, and afford a maximum factor of safety at high speed.

The lead soap active sulphur lubricants are, however, unsatisfactory for use in heavy duty truck hypoid gear axles.

At high speed, where the maximum protection is required in passenger car gears, the active sulphur lubricants function by forming a solid film of iron sulphide on the gear tooth surfaces. This same solid film is formed under the high PV conditions existing in heavy duty truck service at low speeds and high torque. In the passenger car the sulphide film acts as an anti-weld flux and prevents scoring or scuffing. In the heavy duty truck the high frictional

characteristics of the sulphide film increases the surface flash temperature of the sliding or rubbing surfaces sufficiently to reduce the hardness or temper of the extreme surface and permit rapid wear. Thus, a lubricant that affords maximum protection under one set of operating conditions causes rapid wear under a different set of operating conditions.

Under the heavy-duty truck operating conditions of maximum torque at low speeds the chlorine compounds reduce friction but do not furnish sufficient low carrying capacity to prevent scoring. Sulphur is still required as the load carrying agent. The activity of the sulphur, however, must be controlled between rather narrow limits. It must be somewhat more active than the sulphur in a stable sulphurized saponifiable oil and less active than in a lead soap active sulphur lubricant.

By maintaining a careful balance between anti-friction and anti-weld characteristics it is possible to produce a lubricant which offers a fairly satisfactory balance between the "active" or "anti-weld" type required for protection at the maximum passenger car speeds and the "mild" or "anti-friction" type required for maximum protection under the low speed high torque conditions existing in heavy-duty truck service. Unfortunately, however, with the present available commercial materials, it is not possible to meet both extremes and supply a single lubricant which will afford maximum protection to new or "green" gears under all operating conditions. This condition is not as serious as would appear at first sight. Each original equipment manufacturer selects for the initial factory filling the particular type of lubricant which will provide the maximum protection under the most severe service conditions that will be encountered during the run-in period. After 5000 miles on the original factory lubricant the gear teeth rubbing surfaces acquire a superficial polish and the lubrication requirements are lowered to a point where a single lubricant will provide satisfactory lubrication.

#### NOMENCLATURE

Obviously, a system of nomenclature should be based on performance characteristics rather than on chemical composition, and should indicate clearly the type of service for which each lubricant is adapted.

Despite the many objections to the introduction of the term "hypoid lubricant" in 1936, when hypoid gears were first adopted by a large number of passenger-car manufacturers for quantity production, this designation was very largely responsible for the success of the hypoid gear axle.

In 1939, following the introduction of hypoid gear axles in truck service, a number of automotive manufacturers adopted the nomenclature:

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"Passenger-car-duty hypoid lubricant", and

"Truck-duty hypoid lubricant".

The word "duty" was included in this nomenclature in order to emphasize the fact that the operating conditions, and not the type of vehicle alone, must be considered in selecting a rear axle lubricant. A light duty commercial car or truck built on a passenger car chassis, and operating essentially under passenger car conditions, may require a "passenger-car-duty hypoid lubricant" rather than a "truck-duty hypoid lubricant".

Since a number of the so-called mild hypoid lubricants, containing the less active sulphur compounds, will function satisfactorily in service after the gears are run in on the original factory lubricant, the classification has been further extended to include:

"Universal gear lubricant", and

"All-purpose gear lubricant".

It should be thoroughly understood that the so-called "universal gear lubricants" are not "universal" in the sense that they may be used in all types and designs of hypoid axles under all operating conditions. They are "universal" only in that they may be used in current designs of both passenger car and truck axles after the gears have been

operated for the first 5000 miles or break-in period on the factory lubricant.

All lubricants possessing extreme-pressure characteristics, that is, having load carrying properties in excess of straight mineral oils, technically may be classified as "extreme-pressure lubricants". However, this broad classification does not indicate the degree of load carrying ability or the service for which a particular lubricant is suited. Commercially, the term has become restricted to indicate a blend of from 10 to 15% sulphurized saponifiable oil in refined mineral oil, which is intermediate in load carrying properties between straight mineral oil and the mild hypoid or "universal gear lubricant".

## MARKETING PROBLEM

A wide variety of transmission and rear axle lubricants are used by automotive and equipment manufacturers for original filling. These include:

- (1) Black oil
- (2) Refined mineral oil
- (3) Blends of sulphurized Saponifiable in mineral oil
- (4) Lead soap, sulphur, saponifiable, chlorine
- (5) Sulpho-chloro compound
- (6) Chlorine compound, sulphur compound
- (7) Lead soap active sulphur

In the particular applications for which these lubricants are used by the manufacturer they are entirely satisfactory. All are readily available and will continue to be used for the initial factory installation.

Field service presents an entirely different problem. The refiner or marketer cannot be expected to make this complete line of transmission and rear axle lubricants available in several viscosity grades through all retail outlets. The problem resolves itself into one of selecting several lubricants which will cover the entire field and at the same time provide adequate lubrication.

Excluding special units which are covered by specific recommendations all conventional transmissions can be serviced by a sulphurized saponifiable blend or an equivalent "Extreme-Pressure Transmission Lubricant". All spiral bevel rear axles and, after the initial break-in on the factory lubricant, all hypoid axles can be serviced by the "Universal Gear Lubricant". Some marketers for commercial and competitive reasons may desire to eliminate the "Extreme-Pressure Transmission Lubricant" and supply only the "Universal Gear Lubricant" for use in all conventional transmissions and all rear axles.

In accepting these suggestions, relative to the reduction in the number of service lubricants, the petroleum industry must keep in mind that it is impossible for any one person to speak with authority for the entire automotive industry, and that in the last analysis the marketer is responsible for the

quality of his products and must conduct the necessary service tests to insure that his products will adequately meet the lubrication requirements of the different units in which they are used.

## CONCLUSIONS

The cooperative work by the petroleum and automotive industries has resulted in rapid progress in the development of improved automotive gear lubricants.

The trend toward a more efficient utilization of gear materials will continue and will, no doubt, present new lubrication problems. These problems, as they arise, can and will be solved through the cooperative efforts of the two industries.

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# Performance Specifications for Greases\*

By ROBERT C. ADAMS AND HARRISON E. PATTEN

(Continued from previous issue)

In addition to plasticity at low temperature, a suitable lubricant must be stable at the highest temperature to which it will be exposed. There are two ways in which a grease may fail when heated; it may change from a plastic structure to a fluid and run out of the bearing (leakage), or it may separate into a stiffer plastic by losing some of the oil (bleeding). To test for leakage, the bearing which has been used for the cold test is run in the Navy Grease Machine 1938 for 1 hr. at 150 F. and 600 rpm. Not more than 5 per cent of the original charge should leak from the bearing during this test. For separation or bleeding tests, 10 g. of grease are weighed into a perforated nickel filter cone which is exposed in a tared 100-ml. beaker and placed in a drying oven, kept at 150 F. During 50 hr. no oil or molten grease should drip into the beaker. The quantity of such leakage is determined by weighing the beaker with its separated product.

## DIRT IN GREASE

The application of grease lubrication to high-speed precision bearings having minimum clearances makes necessary control of the non-lubricant inclusions in grease. Such things as sand, uncombined lime, metal particles, hair, and vegetable fibers are present

in all greases. In most applications this dirt causes no trouble; at least no casualties have been attributed to it. It seems reasonable, however, that serious damage might be done to a ball bearing if a particle of sand having a diameter twice the clearance between balls and races were thrown into the ball track when the bearing was rotating at high speed. In order to establish standards of cleanliness a quantitative measure of the dirt in grease must be possible.

The apparatus used for such measurements is illustrated in Fig. 8. It consists of a binocular microscope fitted with a micrometer scale in one eyepiece and a mechanical stage. The sample of grease is placed in a U-shaped template 0.006 in. thick on a clean slide and exposed to a 29 to 30 in. vacuum for 10 min. after which a cover glass is placed over the sample. Exposure to vacuum removes entrained air bubbles and clarifies the sample for examination. Magnification of 60 diameters has been found most usable. The sample is illuminated simultaneously from below and transversely. The slide bearing the sample is placed on the stage of the microscope so that the base and sides of the template are parallel to the two motions of the mechanical stage and the eyepiece scale is turned until parallel with the sides of the template and with one end in a corner of the sample. The sample is then racked across the field of view while the observer counts the particles as they pass the eyepiece scale. The individual particles can be measured and their sizes recorded as they are counted.

The results of examination of two greases are illustrated in the curves of Fig. 9. Each ordinate of these curves represents the concentration of particles of the indicated size or larger which were present in the sample. Particles smaller than 0.0005 in. in diameter were counted at a magnification of 113 diameters. Both greases were qual-

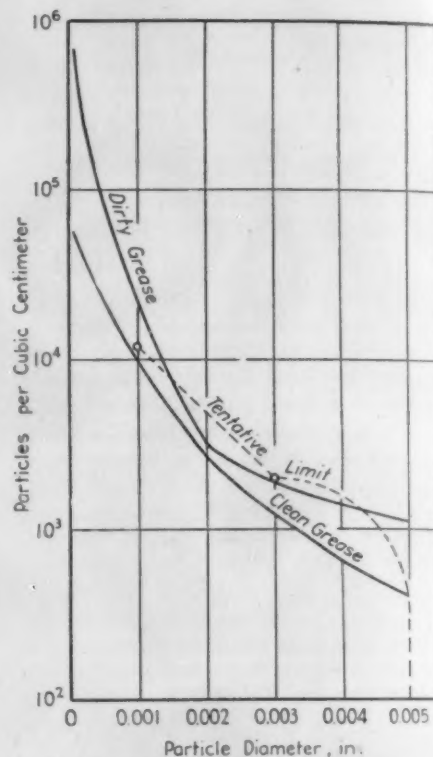


FIG. 9.—Dirt in Representative Greases.

ity products of their respective manufacturers and the cleaner of the two is among the cleanest which has been examined. The absence of particles larger than 0.005 in. in diameter should be secured by adequate screening of the finished grease but low concentrations of foreign material smaller than one or two thousandths of an inch probably can be obtained only by care in the selection of raw materials and cleanliness of equipment during manufacture. A tentative limit of foreign matter in commercially obtainable greases is indicated by the broken line in Fig. 9: namely,

Minimum Diameter, in	Particles per Cubic Centi- meter Above Minimum Diameter
0.001.....	12 000
0.003.....	2 000
0.005.....	0

## ADVANTAGES OF PERFORMANCE SPECIFICATIONS

The use of performance specifications, obtained by coordination of results from special test equipment, has resulted in the purchase of definitely superior lubricants. Previously such materials were obtainable only by proprietary purchase. In the light of these test procedures the requisite properties for a satisfactory lubricant for a spe-

\*Courtesy American Society for Testing Materials

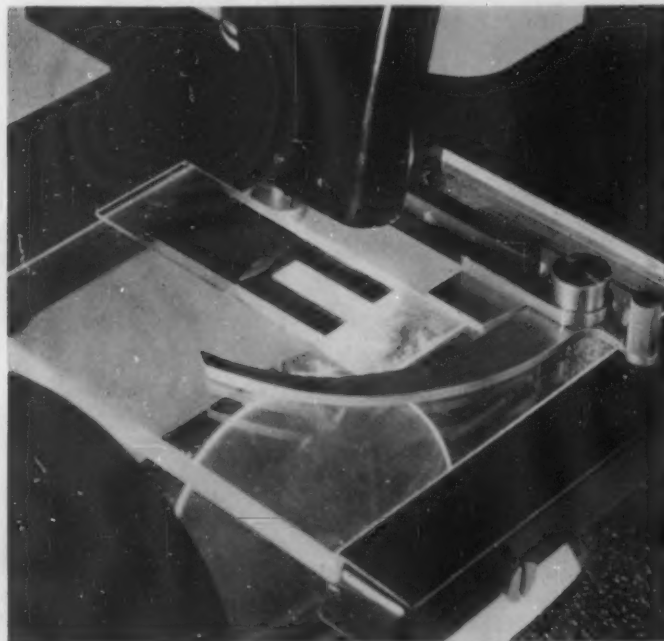


FIG. 8.—Dirt-Count Apparatus.

cific troublesome application can be visualized and tentative requirements can be outlined, the available lubricants can be tested and their efficiency observed. Cooperation between the testing station and the manufacturer often serves to remedy deficiencies with the result that the manufacturer has a premium product to market and the purchaser can obtain a lubricant which gives satisfactory service with a net reduction in the maintenance cost.

A corollary discovery resulting from this investigation is the economy which may result from the use of superior greases. The special testing procedures were developed for specification and purchase of satisfactory greases for difficult applications. Lubricants having the extraordinary properties demanded by these performance specifications are supplied at considerably higher prices than the greases meeting the old composition specifications. Despite this higher unit price, lubrication with these superior lubricants may be more economical than with ordinary lubricants.

Chassis lubrication of a passenger automobile or light truck may be used as a demonstration. Lubrication for such a vehicle at 1000-mile intervals for an estimated 15,000 miles per year would cost \$16.20 per annum, with labor at one dollar per lubrication and grease at eight cents per pound. We have found that chassis lubrication with the medium grade of grease supplied under Navy Aeronautical Specification M-372<sup>2</sup> is required at only 7000- to 8000-mile intervals. This grease is heavier in consistency than

ordinary chassis lubricants so that the labor cost of lubrication with it is greater than with ordinary semifluid chassis lubricants. Even if the labor cost were twice as great, (two dollars per lubrication), the annual cost would be only four dollars, and the grease could cost as much as seventy cents per pound and still provide lubrication for one-third the cost of ordinary lubrication.

In the applications for which performance specifications were developed, monetary considerations are relatively unimportant. Less than 1 lb. of grease will be required for all control bearings of a large bomber or transport plane. The primary consideration is not whether the pound of grease costs ten cents or ten dollars but whether it will provide satisfactory lubrication under all service conditions or will freeze and make the controls inoperable at high altitudes and low temperatures thus hazarding the entire plane with its more precious crew and mission.

#### SUMMARY

The purpose of performance specifications is to obtain the most satisfactory and economical grease for each application regardless of the materials or method used in its manufacture. They should free the manufacturer from arbitrary restrictions in his choice of method and materials, simultaneously opening to him the opportunity for recognition of truly superior products. The beginning which has been made offers promise of universal use to the mutual advantage of both producers and consumers of grease.

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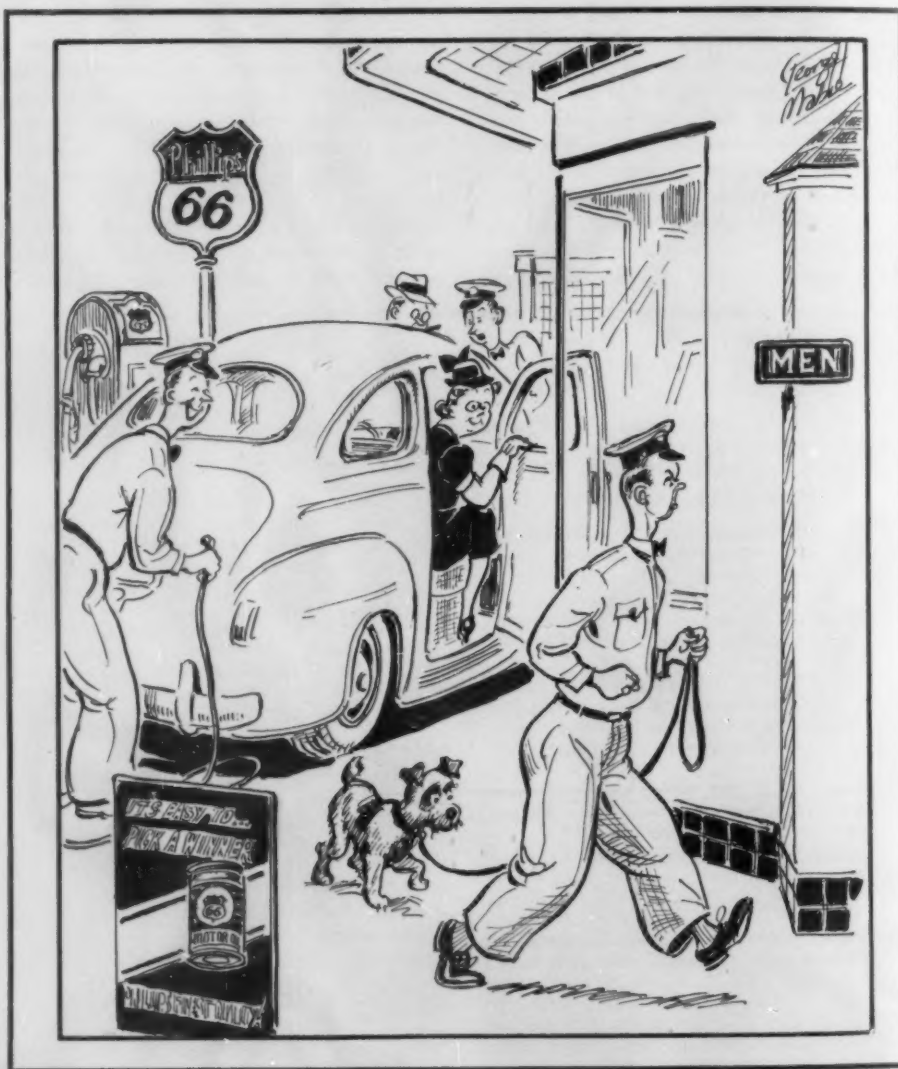
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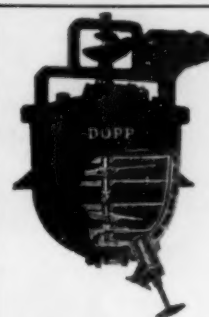
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## Car Manufacturers' Recommendations\*

### LUBRICATING UNDERDRIVE TRANSMISSIONS ON CHRYSLER AND DE SOTO

#### Optional Recommendations Established

The Chrysler Corporation has released optional recommendations for the Chrysler Vacamatic Underdrive and De Soto Simplimatic Underdrive Transmissions. These recommendations, as they will appear in 1942 Chrysler Six, Chrysler Eight, and De Soto instruction books, and which are retroactive for the underdrive units on 1941 Chrysler Six and De Soto, are as follows:

Check transmission lubricant level every 2,000 miles. It should be kept up to the filler hole in the side of the transmission case.

Drain every 15,000 miles or twice yearly (seasonal), whichever drainage period occurs first. During the first 15,000 miles, however, the original lubricant in the transmission when the car is delivered should be used, regardless of climatic conditions. If necessary to add lubricant during this mileage period, use the preferred lubricant recommended below or, if desired, the optional lubricants may be used according to climatic conditions or the season of the year.

When the speedometer registers 15,000 miles the transmission should be drained, washed out with a good flushing oil (not kerosine), and refilled with new lubricant, according to the following recommendations. Lubricant changes should then be made under normal conditions every 15,000 miles or twice yearly—whichever drainage period occurs first.

#### Preferred Lubricant (All Seasons)

A highly refined mineral oil of the viscosity range of No. 20W engine oil, with which has been compounded 10% of sulphur saponifiable base. The pour point of this blend should be below the lowest anticipated atmospheric temperature.

#### Optional Recommendations

For atmospheric temperatures above plus 32° F. SAE 30 engine oil-quality grade.

For atmospheric temperatures below plus 32° F. No. 20W engine oil-quality grade.

The pour point of this oil should be below the lowest anticipated atmospheric temperature.

It is recommended that Hypoid Gear Lubricants not be used in the Vacamatic or Simplimatic Underdrive Transmission.

The interpretation of these optional recommendations means that No. 20W engine oil may be used as a general winter lubricant.

Should atmospheric temperatures rise

above plus 32° F., however, a change of lubricant is not necessary until the next mileage or seasonal change. No. 20W oil may be used with safety for all normal driving conditions, even though the winter season is mild and the atmospheric temperatures abnormally high for winter.

SAE 30 oil may also be used in the transmission during the winter months in tropical climates or where winter conditions are mild. Therefore, unless the temperature during the winter months should fall considerably below plus 32° F., a change may not be necessary until the next mileage period.

### DRAINING ENGINE OIL ON HYDRA-MATIC CARS

One or two cases have recently been reported of filling station attendants partially draining the Hydra-Matic Drive on 41-Series Cadillac cars at the same time they were draining the engine oil.

This mistake is evidently due to the similarity in appearance between the engine oil drain plug and the rear drain plug on the Hydra-Matic Drive, although there should be no confusion, as the Hydra-Matic plug is in a location similar to that of a conventional transmission drain plug.

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